Environmental, Health, and Safety Guidelines for Waste Management Facilities

Introduction

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP)[1]. When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These industry sector EHS guidelines are designed to be used together with the **General EHS Guidelines** document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary. A complete list of industry-sector guidelines can be found at: www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them.

The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account. The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons. When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

Applicability

The EHS Guidelines for Waste Management cover facilities or projects dedicated to the management of municipal solid waste and industrial waste, including waste collection and transport; waste receipt, unloading, processing, and storage; landfill disposal; physico-chemical and biological treatment; and incineration projects.[2] Industry-specific waste management activities applicable, for example, to medical waste, municipal sewage, cement kilns, and others are covered in the relevant industry-sector EHS Guidelines, as is the minimization and reuse of waste at the source. This document is organized according to the following sections:

Section 1.0 — Industry-Specific Impacts and Management
Section 2.0 — Performance Indicators and Monitoring
Section 3.0 — References and Additional Sources
Annex A — General Description of Industry Activities

[1] Defined as the exercise of professional skill, diligence, prudence and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity as well as varying levels of financial and technical feasibility.

[2] This document covers the most common commercial methods of waste management. It does not cover other activities such as the management of radioactive wastes, co-incineration at combustion plants, or deep well injection.

1.0 Industry-Specific Impacts and Management

The following section provides a summary of the most significant EHS issues associated with Waste Management, which occur during the operational and decommissioning phases, along with recommendations for mitigating these impacts.

Recommendations for the management of EHS impacts common to most large industrial facilities during the construction phase are provided in the **General EHS Guidelines**, as are other operational phase issues, such as noise, common to many industrial activities.

1.1 Environment

Municipal solid waste (MSW) is typically managed separately from industrial hazardous and non-hazardous wastes; therefore, environmental impacts associated with management of MSW and industrial wastes are addressed separately below.

1.1.1 Municipal Solid Waste

Municipal solid waste (MSW) is generally defined as the wastes (other than sewage and air emissions) generated in and usually collected by a municipality. MSW is extremely variable in composition, depending on the income and lifestyle of the generators. As shown in Table 1, MSW includes household refuse, institutional wastes, street sweepings, commercial wastes, as well as construction and demolition debris. MSW may include paper and packaging materials; foodstuffs; vegetable matter such as yard debris; metal; rubber; textiles; and potentially hazardous materials such as batteries, electrical components, paint, bleach, and medicines. MSW may also contain varying amounts of industrial wastes from small industries, as well as dead animals and fecal matter. Environmental impacts and associated mitigation measures applicable to MSW collection and transport; waste receipt, unloading, processing, and storage; biological treatment; incineration; and landfilling are described below.

Table 1 - Sources and Types of Municipal Solid Waste

Source	Typical Waster Generators	Types of Solid Waste
Residential	Single and multifamily dwellings	Food waste, paper, cardboard, plastic, textiles, leather, yard waste, wood, glass, metal, ash, special waste (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires) and household hazardous waste
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants	Housekeeping waste, packaging, food waste, construction and demolition materials, hazardous waste, ash, special waste
Commercial	Stores, hotels, restaurants, markets, office buildings	Paper, cardboard, plastic, wood, food waste, glass, metal, special waste, hazardous waste
Institutional	Schools, hospitals, prisons, government centers	Same as commercial
Construction and Demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, etc.
Municipal Services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweepings; landscape and tree trimmings; general waste from parks, beaches and other recreational areas; sludge from water and wastewater treatment plants
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process waste, scrap materials, off-specification products, slag, tailings
Source: World Bank (2005)		

Waste Collection and Transport

Litter and clandestine dumping

The causes of littering and clandestine dumping in urban areas occur because of inadequate availability of litter bins along walkways, inadequate public awareness of their responsibilities as urban dwellers, and inadequate refuse collection service. Littering occurs everywhere and often into drains, while clandestine dumping is commonly on vacant lots, public spaces, or along waterways. Accumulated waste may attract disease vectors, contribute to clogging of drainage and sewerage networks, make waste readily accessible to neighborhood animals and birds, and pollute waterways.

Recommended management strategies to minimize litter and clandestine dumping include:

- Encourage use of containers or bags for waste at the point of collection for each household and establishment;
- Implement a regular collection schedule with sufficient frequency to avoid accumulation of garbage;
- Use vehicles appropriate for the geographic conditions and waste types to maximize reliability of collection (e.g., compactor trucks may be appropriate for neighborhoods with wide streets and low-density trash, while smaller vehicles may be appropriate for neighborhoods with narrow streets and higher-density garbage);
- Encourage separation of recyclable materials at the point of generation, so that the collection points do not become sorting points for informal sector waste pickers;
- Cover collection and transfer vehicles along the entire route of transport to avoid windblown litter;
- Clean vehicles used for waste hauling before transportation of any goods, including compost;
- Encourage residents to put waste out at designated times and locations;
- Where possible, blocking off access to dumping sites and fining illegal dumpers.

Air Emissions

Air emissions from MSW collection and transport include, dust and bio-aerosols, odors, and vehicle emissions.

Dust, Bio-aerosols, and Odors

Dust can include nuisance dust, hazardous dust (e.g., containing asbestos or silica), and bioaerosols (i.e., particles in the air consisting wholly or partially of microorganisms). Bioaerosols are of particular concern to the health of waste workers and have been show to be the source of reduced pulmonary function and increased respiratory disease for those in immediate proximity to waste sweeping and collection activities.[3] Recommended management strategies to minimize dust, bio-aerosols, and odors include:

- Establishing frequent waste collection schedules;
- Instituting a washing program for waste collection vehicles and for company-owned waste collection and transfer containers;
- Promoting the use of bags to reduce the odors from soiling of waste collection and transport equipment.

Vehicle Emissions

Emissions from on-road vehicles may be regulated through national or regional programs. In the absence of these, specific measures to prevent, minimize, and control vehicle air emissions during waste collection and transport include the following:

- Optimize waste collection routes to minimize distance traveled and overall fuel use and emissions

3 Additional information is provided in Cointreau, S. (2006).

- Implement transfer stations for small vehicles to consolidate waste into large vehicles for transportation to a treatment or disposal facility;
- Waste collection and transport vehicle owners and operators should implement the equipment manufacturers' recommended engine maintenance, along with the mechanical maintenance for the safe operation of the vehicle, including proper tire pressure.;
- Drivers should also be instructed on the benefits of driving practices which reduce both the risk of accidents and fuel consumption, including measured acceleration and driving within safe speed limits (working with garbage truck drivers can save as much as 25% on fuel use and reduce maintenance by 15%).

Additional fleet management recommendations are presented in the **General EHS Guidelines**.

Waste Receipt, Unloading, Processing, and Storage

Control of the incoming waste stream is necessary to ensure safe and effective processing, treatment, and disposal of the waste and the quality of end products (e.g., compost). While procedures may vary depending on the nature of the waste and necessary processing methods, recommended measures include:

- Visually evaluate, weigh, and document incoming waste loads;
- Reject or, if the facility is equipped to process the waste, segregate potentially hazardous materials or wastes identified, including infectious waste, and manage as a hazardous or infectious waste, as applicable;
- Analyze suspected hazardous materials before acceptance so that they are segregated relative to compatibility and so that they can be adequately treated and disposed of;
- If possible, isolate size reduction equipment (e.g., shredders or grinders) in an explosion-proof area with proper ventilation and pressure relief to reduce the impacts of potential explosions that could be caused by materials such as gas cylinders and ignitable liquids that may be present in MSW. Visual inspection of the incoming waste, along with sorting and removal procedures, can minimize this potential hazard;
- Separate recoverable secondary materials for recycling and organic waste for composting to the extent practical.

Contaminated Runoff

Leachate from waste piles caused by exposure to precipitation and from residual liquids in the waste itself may contain organic matter, nutrients, metals, salts, pathogens, and hazardous chemicals. If allowed to migrate, leachate can contaminate soil, surface water, and groundwater potentially causing additional impacts such as eutrophication and acidification of surface water and contamination of water supplies.

Recommended contaminated runoff management strategies include:

- When siting, consider the proximity of waste handling and storage areas to water supply wells for people and animals, irrigation canals, and surface water bodies that support aquatic life and the ability to prevent contaminated leachate and drainage from entering surface and ground water;
- Use impermeable materials for roads, waste processing and storage areas, and vehicle washing areas, and install curbs to prevent runoff to permeable areas;
- Collect runoff and leachate from areas used for waste storage, and treat runoff to meet applicable environmental standards before discharge to surface water or the municipal sewage system (e.g., screen to remove large material, install silt traps to remove particulates, and

remove separate-phase liquids with an oil/water separator). Discharge to the municipal sewage system (via pipe or tanker truck), where available, is preferred for runoff from waste storage and handling areas;

- Re-use collected water in on-site disposal processes to the extent practical or store with collected leachate awaiting treatment.

In addition, management strategies for contaminated runoff from vehicles include:

- Cover containers during transport,
- Ensure vehicle equipment is designed to collect drainage and that it is held in a sump container until the vehicle reaches a safe discharge location.

Litter

The following measures are recommended to prevent, minimize, and control litter and solid waste during waste receipt, unloading, processing, and storage:

- Provide adequate storage for waste not immediately treated or disposed of;
- Implement good housekeeping procedures;
- Consider use of enclosed/covered areas for waste tipping, shredding, compacting, etc.;
- Install catch fences and netting to trap windblown litter.

Air Emissions

The following measures are recommended to prevent, minimize, and control vehicle emissions and emissions of dust, odors, and bioaerosols during waste receipt, unloading, processing, and storage:

- Select vehicles and containers that minimize air emissions during waste loading and unloading;
- Design drop-off points to minimize queuing of vehicles;
- Sweep waste management areas and roads frequently and use water spray for dust control where needed;
- Pre-treat wastes as needed (e.g., solidification, encapsulation, or wetting sufficient to reduce dust but without forming leachate);
- Use enclosed waste handling and storage areas for malodorous wastes or wastes that generate hazardous dust (e.g., asbestos). Enclosed waste storage and handling areas are preferred for all wastes;
- Use extraction system to remove dust from working areas, buildings, and storage vessels, and treat as needed to control particulate emissions (e.g., bag filter);
- Remove, treat, or dispose of all biological/malodorous wastes in an expeditious manner;
- Use odor-neutralizing sprays where necessary;
- Use negative pressure in processing buildings and appropriate air filtration (e.g., biofilter) to remove odor,

Noise and Vibration

Principal sources of noise and vibration include truck traffic; loading equipment (e.g., cranes, wheeled loaders), stationary compactors, balers, grinders, and other treatment and conveyance systems.

Recommended noise management strategies include:

- Construct a buffer zone between the facility and the external environment or locate facilities away from sensitive receptors;
- Include noise and vibration considerations during design, including use of models to predict noise levels at specified noise-sensitive locations, using standardized sound power levels for construction plant;
- Maintain site roads in good condition to reduce noise and vibration from vehicle movements;

- Use acoustic screens around fixed/mobile plant and equipment;
- Select equipment that has low noise emission levels;
- Fit silencing equipment to plant, e.g. baffles/mufflers;
- Use buildings to contain inherently noisy fixed plant equipment (e.g., locate waste shredder in the tipping hall, and enclose tipping hall on all sides) and consider use of sound-insulating materials in construction.

Biological Treatment

Biological treatment includes composting with other organic materials for the preparation of soil products[4] (i.e., aerobic treatment), and anaerobic digestion. To maximize the usability of end products, waste should not be accepted that contains organics that are contaminated by potentially hazardous chemicals (e.g., PCBs, chlordane and other pesticides, heavy metals and metalloids) and/or pathogenic substances and micro-organisms (e.g., prions, viruses, bacteria, and parasites) that will not be rendered harmless by the process or may constitute a health or environmental risk. This may include certain clinical waste and other related wastes of clinical origin, and diseased carcasses, or contaminants classified as hazardous or industrial wastes.[5]

Leachate and Runoff

Leachate and runoff from waste storage and processing areas may contain organic material (biochemical oxygen demand (BOD)), phenols, nitrates, phosphorous, dissolved metals, and other contaminants. If treated wood is processed, wood preservative chemicals, such as creosote and chromated copper arsenate, and their degradation products may be present. Municipal waste may contain human and animal fecal matter and blood which have a wide range of disease micro-organisms. Some household chemicals can possess hazardous properties; examples include pesticides, solvents, paints, batteries, used oils, pharmaceuticals, etc.

The following measures are recommended to prevent, minimize, and control leachate generation and discharge from biological treatment operations:

- Install a drainage layer underneath the processing area to provide adequate leachate drainage from composting organics. This may consist of a bed of coarse material such as wood chips, or alternatively the processing platform may permanently incorporate a drainage layer designed to withstand the loading, working and removal of material. For small-scale compost facilities or in dry areas, an adsorbent material can be incorporated in the compost and at the base of the pile;
- The material processing or storage areas of the facility should have a leachate barrier system that forms a secure barrier between the groundwater, soil, and substrata and the composting or stored organics, as well as systems for collecting and treating leachate;
- Design and maintain the slope and orientation of windrows and/or leachate drains such that free drainage of leachate to a collection drain is facilitated and ponding of leachate is avoided; shape the piles and windrows to maximize run-off and hence reduce infiltration;
- Store leachate in a lined earthen basin or in aboveground storage tanks;
- For anaerobic digestion, maximize recycling of wastewater to the reactor;

[4] Compost is organic material that can be used as a soil amendment or as a medium to grow plants. Mature compost is a stable material with a content called humus that is dark brown or black and has a soil-like, earthy smell. It can be created by combining organic wastes (e.g., yard trimmings, food wastes, manures) in proper ratios into piles, rows, or vessels; adding bulking agents (e.g., wood chips) as necessary to accelerate the breakdown of organic materials; and allowing the finished material to fully stabilize and mature through a curing process (as defined by the US EPA (http://www.epa.gov/epaoswer/non-hw/composting/basic.htm)).

[5] Additional information on composting is provided in Chapter 7 (Composting) of the Decision Maker's Guide to Solid Waste Management, Volume II, EPA, 1995 (http://www.epa.gov/garbage/dmg2.htm)

- Measure total organic carbon (TOC), chemical oxygen demand (COD), nitrogen (N), phosphorus (P) and chlorine (Cl) levels in the inlet and outlet flows from an anaerobic digester. When a better control of the process is required, or a better quality of the waste output, monitoring of additional parameters may be necessary;
- Operate an anaerobic digester under thermophilic digestion conditions, in order to increase the pathogen destruction, biogas production rate (hence higher energy recovery) and the retention time
- Maintain ideal composting conditions such as[6]:
  - Carbon: nitrogen (C:N) ratio between 25:1 and 35:1
  - Moisture content of 50 to 60 percent of total weight during treatment (and less than 50 percent for marketing following screening)
  - Balance between particle size and void space to promote rapid decomposition. Void space should be sufficient to achieve a 10 to 15 percent oxygen level within the pile in aerobic systems
  - Optimum temperature levels which can range between 32 and 60 degrees Celsius. Pathogen destruction can be achieved by attaining and maintaining a temperature of 55 degrees Celsius for three days in a vessel composting system or 15 days in a windrow system
  - pH of between 6 and 8.

Air Emissions

Releases to the air can include direct stack emissions and fugitive emissions associated with biological processes, as well as emissions from burning of biogas. Direct air emissions can include bioaerosols, particulate matter/dust, ammonia, amines, volatile organic compounds (VOCs), sulfides, odors, etc. The following measures are recommended to prevent, minimize, and control air emissions from biological treatment:

- Use mist spray to keep down dusts, especially during and prior to loading or other handling procedures.
- Use windrow turning equipment that is specially designed to minimize air emissions, as opposed to wheeled loaders or conveyor loaders that drop wastes into piles.
- For highly odorous wastes, use closed feed bunkers constructed with a vehicle sluice; for less odor-intensive wastes, use automated and rapid action doors (opening times of the doors being kept to a minimum) in combination with an appropriate exhaust air collection device resulting in an under pressure in the treatment hall.
- Enclose leachate drains to reduce the emission of odors.
- Minimize the amount of water added to compost (e.g., by covering compost material) to avoid anaerobic conditions that can cause hydrogen sulfide odors if the compost mixture contains sulfur-containing materials.

Biomass and biogas combustion emissions depend on the type of biomass material and combustion method and can include particulate matter, nitrogen oxide (NO_X), sulfur oxide (SO_X), carbon monoxide (CO), hydrogen sulfide (H_2S), and VOCs. When using biomass or biogas as a fuel source for power generation, reference should be made to the **General EHS Guidelines** for emissions guideline values and the selection of appropriate emissions prevention and control techniques.

Fire

Biodegradable wastes can be combustible and aerobic degradation can produce sufficient heat to cause spontaneous combustion in certain circumstances. Wastes can, in some instances, also contain ashes and other readily ignitable materials that burst into flame under wind conditions, or when contacting flammables. In landfills, methane is generated by

[6] US EPA (1995)

anaerobic digestion and can potentially ignite if it encounters an ignition source within or external to the landfill. Methane in landfill gas can become trapped in underground cavities, and even move along geologic discontinuities, to pose a risk of explosion.

Recommended fire prevention and control strategies include:

- For composting, avoid conditions that can lead to spontaneous combustion (e.g., moisture between 25 – 45 percent and temperatures above about 93ºC. This can be achieved for example by keeping windrows less than about 3m high and turning them when the temperature exceeds 60ºC);
- Collect biogas for use or treatment (e.g. energy recovery or flaring);
- Provide a fire alarm system, including temperature sensors in the waste being treated;
- Design the facility for access by firefighting equipment, including clear aisles among windrows and access to an adequate water supply.

MSW Incineration Facilities

Air Emissions

Air emissions from incineration depend on the specific waste composition and the presence and effectiveness of air pollution control systems. Polluting emissions may include carbon dioxide (CO_2), CO, NO_X, sulfur dioxide (SO_2), particulate matter, ammonia, amines, acids (HCL, HF), VOCs, dioxins/furans, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), metals (Hg), and sulfides, etc., depending on the waste content and combustion conditions.

The following measures are recommended to prevent, minimize, and control air emissions:

- Conduct waste segregation and/or presorting to avoid incineration of wastes that contain metals and metalloids that may volatilize during combustion and be difficult to control through air emission technology (e.g., mercury and arsenic);
- Follow applicable national requirements and internationally recognized standards for incinerator design and operating conditions, mainly rapid quenching of the flue gas after leaving all combustion chambers and before entering any dry particulate matter air pollution control device but also combustion temperature, residence time, and turbulence.[7] Standards for stationary incinerators which include temperature and afterburner exit gas quenching (i.e. rapid temperature reduction) requirements are preferred in order to nearly eliminate dioxins and furans;
- Introduce wastes into the incinerator only after the optimum temperature is reached in the final combustion chamber.
- The waste charging system should be interlocked with the temperature monitoring and control system to prevent waste additions if the operating temperature falls below the required limits;
- Minimize the uncontrolled ingress of air into the combustion chamber via waste loading or other routes;
- Optimize furnace and boiler geometry, combustion air injection, and, if used, NO_X control devices using flow modeling;
- Optimize and control combustion conditions by the control of air (oxygen) supply, distribution and temperature, including gas and oxidant mixing; the control of combustion

[7] For example, according to Article 6 of EU Council Directive 2000/76, the gas resulting from the incineration process should be raised, after the last injection of combustion air to a temperature of 850 degrees Celsius (1,100 degrees Celsius for hazardous wastes with a content greater than 1% of halogenated organics) for a period of two seconds. Additional details on operating conditions are provided in this reference. Other sources of emissions standards include the U.S. EPA regulations for air emissions from stationary sources at 40 CFR Part 60.

temperature level and distribution; and the control of raw gas residence time;

- Implement maintenance and other procedures to minimize planned and unplanned shutdowns;
- Avoid operating conditions in excess of those that are required for efficient destruction of the waste;
- Use auxiliary burner(s) for start-up and shut-down and for maintaining the required operational combustion temperatures (according to the waste concerned) at all times when unburned waste is in the combustion chamber.
- Use a boiler to transfer the flue-gas energy for the production of electricity and/or supply of steam/heat, if practical;
- Use primary (combustion-related) NO_X control measures and/or selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) systems, depending on the emissions levels required;
- Use flue gas treatment system for control of acid gases, particulate matter, and other air pollutants;
- Minimize formation of dioxins and furans by ensuring that particulate control systems do not operate in the 200 to 400 degrees Celsius temperature range; identifying and controlling incoming waste composition; using primary (combustion-related) controls; using designs and operation conditions that limit the formation of dioxins, furans, and their precursors; and using flue gas controls;
- Consider the application of waste-to-energy or anaerobic digestion technologies to help off-set emissions associated with fossil fuel based power generation.[8]

Ash and Other Residuals

Combustion of solid wastes generates ash and other material remaining after incineration. Solid wastes may also be generated from treatment of wastewater from flue gas treatment (FGT).

The following measures are recommended to prevent, minimize, and control solid waste from incineration:

- Design the furnace to, as far as possible, physically retain the waste within the combustion chamber (e.g. narrow grate bar spacing for grates, rotary or static kilns for appreciably liquid wastes), and use a waste throughput rate that provides sufficient agitation and residence time of the waste in the furnace at sufficiently high temperatures, including any ash burn-out areas, in order to achieve a total organic carbon (TOC) value in the ash residues of below 3 wt percent and typically between 1 and 2 wt percent.
- Manage bottom ash separately from fly ash and other flue gas treatment residues to avoid contamination of the bottom ash for its potential recovery;
- Separate remaining ferrous and non-ferrous metals from bottom ash as far as practicably and economically viable, for their recovery;
- Treat bottom ash on or off-site (e.g., by screening and crushing) to the extent that is required to meet the specifications set for its use or at the receiving treatment or disposal site (e.g., to achieve a leaching level for metals and salts that is in compliance with the local environmental conditions at the place of use);
- Bottom ash and residuals should be managed based on their classification as hazardous or non-hazardous materials. Hazardous ash should be managed and disposed of as hazardous waste. Non-hazardous ash may

[8] The possibility of applying waste-to-energy technologies depends on a number of issues which may include the project design specifications established by local government as well as laws applicable to the generation and sale electricity . Also, it should be noted that recycling options may often save more energy than what is generated by incineration of mixed solid waste in a waste-to-energy facility .

be disposed of in an MSW landfill or considered for recycling in construction materials.[9]

Water Effluents

Cooling systems generate cooling tower blowdown, which is addressed in the **General EHS Guidelines**. In addition, flue gas treatment generates wastewaters requiring treatment and disposal.

To prevent, minimize, and control water effluents, wastewater from flue gas treatment should be treated as necessary, e.g., using filtration coagulation, precipitation, and filtration to remove heavy metals, and neutralization.

Noise

Principal sources include exhaust fans and resulting in noise from the outlet of the stack; cooling system (for evaporation cooling and especially for air cooling); and turbine generators.

Measures to address noise impacts are addressed in the **General EHS Guidelines**. Additional recommended measures to prevent, minimize, and control noise from incineration include use of silencers on air coolers and chimneys, as necessary.

Landfilling

A sanitary landfill is a carefully engineered, structurally stable formation of segregated waste cells separated by soil cover material, with base and side slopes designed to minimize infiltration and facilitate collection of leachate. Landfills are sited, designed and operated to isolate the wastes from the surrounding environment, particularly groundwater. Even after closure, landfills required long-term care, including maintenance of the cap system, collection and treatment of leachate, collection and flaring or utilization of landfill gas, and monitoring of groundwater so that the waste remains isolated. Thus, the EHS impacts of eventual decommissioning or closure and long-term operation and maintenance of a landfill need to be considered in the system design. Specific closure procedures should focus on the preservation of the long-term integrity and security of the site, preferably with a minimum of maintenance.

Landfill operators, working in coordination with local regulatory authorities, should explore and implement opportunities to minimize the landfill disposal of municipal wastes which contain metals, such as mercury, which may be released due to crushing of waste materials. Segregation and presorting of these materials should be performed to the extent feasible.

Landfill Siting

The location of the landfill should take into account potential impacts associated with releases of polluting substances including the following:[10]

- Proximity to residential, recreation, agricultural, natural protected areas, or wildlife habitat and areas prone to scavenging wildlife, as well as other potentially incompatible land uses:
    - Residential development should be typically further than 250 meters from the perimeter of the proposed landfill cell development to minimize the potential for migration of underground gaseous emissions
    - Visual impacts should be minimized by evaluating locational alternatives
    - Siting should be further than 3 km of a turbojet airport and 1.6 km of a piston-type airport or as permitted by the aviation authority fully considering potential threats to air safety due to attraction and presence of birds
- Proximity and use of groundwater and surface water resources;

[9] EPA (http://www.epa.gov)

[10] Additional detail on siting is provided in Cointraeu (2004) and European Union Council Directive (1999).

- Private or public drinking, irrigation, or livestock water supply wells located downgradient of the landfill boundaries should be further than 500 meters from the site perimeter, unless alternative water supply sources are readily and economically available and their development is acceptable to regulatory authorities and local communities
- Areas within the landfill boundaries should be located outside of the 10-year groundwater recharge area for existing or pending water supply development.
- Perennial stream should not be located within 300 meters downgradient of the proposed landfill cell development, unless diversion, culverting or channeling is economically and environmentally feasible to protect the stream from potential contamination.

- Site geology and hydrogeology;
  - Landfills should be located in gently sloped topography, amenable to development using the cell (bund) method, with slopes which minimize the need for earthmoving to obtain the correct leachate drainage slope of about 2%
  - Groundwater's seasonally high table level (i.e., 10 year high) should be at least 1.5 meters below the proposed base of any excavation or site preparation to enable landfill cell development
  - Suitable soil cover material should be available on-site to meet the needs for intermediate (minimum of 30 cm depth) and final cover (minimum of 60 cm depth), as well as bund construction (for the cell method of landfill operation). Preferably, the site would have adequate soil to also meet required cover needs (usually a minimum of 15 cm depth of soil) [11]
- Potential threats to landfill site integrity from natural hazards such as floods, landslides, and earthquakes:
  - Landfills should be sited outside of a floodplain subject to 10-year floods and, if within areas subject to a 100-year flood, amenable to an economic design which would eliminate the potential for washout
  - There should be no significant seismic risk within the region of the landfill which could cause destruction of berms, drains or other civil works, or require unnecessarily costly engineering measures; otherwise, side slopes should be adjusted accordingly to prevent failure in the event of seismic activity
  - No fault lines or significantly fractured geologic structure should be present within 500 meters of the perimeter of the proposed landfill cell development which would allow unpredictable movement of gas or leachate
  - There should be no underlying limestone, carbonate, fissured or other porous rock formations which would be incompetent as barriers to leachate and gas migration, where the formations are more than 1.5 meter in thickness and present as the uppermost geologic unit above sensitive groundwaters.

Leachate Generation

Landfill leachate contains dissolved constituents derived from the interstitial waters of the disposed waste as well as its degradation products. It also may contain some suspended solids, including pathogens. If not collected and treated, leachate can migrate from the landfill and contaminate soil, groundwater, and surface water. Leachate and site monitoring are used to confirm that the engineered landfill systems effectively isolate the waste, both during operation of the landfill

[11] Daily cover needs can be alternatively met by using removable tarps, other relatively inert materials (i.e., compost residuals), or by removing the previously laid daily soil cover at the start of each day for reuse at the end of the same day. For purposes of siting, assume that at least 1 cubic meter of daily, intermediate, and final compacted soil cover is needed for every 6 cubic meters of compacted refuse.

and after closure. Leachate from a MSW landfill typically is very high in nitrogen (as ammonium), chloride, and potassium, as well as dissolved biological oxygen demand and chemical oxygen demand organics.

The following measures are recommended to prevent, minimize, and control leachate generation from MSW landfills:

- Site landfills in areas with stable geology and avoid siting near particularly vulnerable or sensitive ecosystems and groundwater and surface water resources;
- Design and operate the landfill in accordance with applicable national requirements and internationally recognized standards to minimize leachate generation, including the use of low-permeability landfill liners[12] to prevent migration of leachate as well as landfill gas, a leachate drainage and collection system, and landfill cover (daily, intermediate, and final) to minimize infiltration;[13]
- Treat leachate onsite and/or discharge to municipal wastewater system. Potential treatment methods include aerated lagoons, activated sludge, anaerobic digestion, artificial wetlands, re-circulation, membrane filtration, ozone treatment, peat beds, sand filters, and methane stripping;
- Minimize the daily exposed working face and use perimeter drains and landfill cell compaction, slopes and daily cover materials to reduce infiltration of rainfall into the deposited waste;
- Prevent run-on of precipitation into the active area of the landfill (e.g., by use of berms or other diversions); systems should be designed to handle the peak discharge from a 25-year storm;
- Collect and control run-off from the active area of the landfill; the system should be designed to handle the discharge from a 24-hour, 25-year storm. Runoff is typically treated together with leachate from the site.

Groundwater and Leachate Monitoring

Recommended measures for groundwater and leachate monitoring include the following:

- Measure and record the quantity and quality of leachate generated. Changes in leachate quantity or quality not attributable to weather or other factors may indicate changes in the liner, leachate collection, or landfill cover systems;
- Install groundwater monitoring wells outside the landfill perimeter at locations and depths sufficient to evaluate whether leachate is migrating from the landfill into the uppermost groundwater unit. This groundwater monitoring network should usually include, at a minimum, one monitoring well located in the upgradient groundwater flow direction from the landfill and two monitoring wells located in the down gradient direction. The groundwater monitoring system should be consistent with applicable national regulations and internationally recognized standards.[14]
- Regularly sample the monitoring wells and analyze for constituents, selected based on:
    - o The types, quantities, and concentrations of constituents in wastes managed in the landfill

[12] Liner systems for MSW landfills can consist of a combination of geological barrier with an overlying bottom liner and leachate drainage layer. Permeability and thickness requirements may range from a hydraulic conductivity of 1 x 10^{-7} centimeters/second for a 0.6-meter layer of compacted soil overlaid by a 30-mil flexible membrane liner (60-mil if made from high density polyethylene (HDPE)) (see U.S. EPA Regulations at 40 CFR Part 258) to a 1 meter thickness and hydraulic conductivity of 1 x 10^{-9} meters/second for the combined geological barrier and liner system with a 0.5 meter drainage layer (see European Union Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste).

[13] For additional detailed design criteria refer to Basel Convention Guidelines on Specially Engineered Landfill, Basel Convention Series/SBC No. 02/03; U.S. EPA Regulations at 40 CFR Part 258; and European Union Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste.

[14] See, for example, U.S. EPA regulations at 40 CFR Part 258 Subpart E.

- The mobility, stability, and persistence of waste constituents their reaction products in the unsaturated zone beneath the waste management area
- The detectability of indicator parameters, waste constituents, and reaction products in ground water;
- The constituent concentrations in the groundwater background.

Landfill Gas Emissions

MSW contains significant portions of organic materials that produce a variety of gaseous products when dumped, compacted, and covered in landfills. Oxygen in a landfill is quickly depleted, resulting in anaerobic bacterial decomposition of the organic materials and the production of primarily carbon dioxide and methane. Carbon dioxide is soluble in water and tends to dissolve in the leachate. Methane, which is less soluble in water and lighter than air, tends to migrate out of the landfill, resulting in landfill gas that is typically about 60 percent methane and 40 percent CO_2, with trace amounts of other gases. Some MSW landfills are designed to maximize anaerobic degradation and production of landfill gas, which can be burned for energy. In addition, operation of landfills can generate dust and odors. Landfill gas is not generated, or in lesser quantities, if the waste material is primarily inert, such as construction debris.

Recommended methods to control and monitor landfill gas emissions include the following:

- Include landfill gas collection system designed and operated in accordance with applicable national requirements and recognized international standards including recovery and pre-use processing or thermal destruction through an efficient flaring facility.[15] Prevent condensation from accumulating in extraction systems by arranging the pipe work to fall to a removal point such as a knock out-pot.
- Use landfill gas as fuel if practical, or treat before discharge (e.g., by using enclosed flare or thermal oxidation if methane content is less than about 3 percent by volume).
- Use gas blowers (boosters) of sufficient capacity for the predicted gas yield and constructed of materials appropriate for landfill gas duty; blowers should be protected by flame arrestors at both gas inlet and outlet.
- Install and regularly sample boreholes surrounding the landfill to monitor for migration of landfill gas.

Carbon financing may also be considered, including opportunities implemented through the host-country Joint Implementation of the United Nations Network Convention on Climate Change.

Recommended methods to control dust and odor emissions include the following:

- Compact and cover waste promptly after discharge from the vehicle delivering the waste
- Minimize open tipping face area
- Dispose of odorous sludge in covered trenches
- Restrict acceptance of loads known to be particularly odorous
- Restrict tipping activities during periods of adverse weather (e.g., wind toward sensitive receptors)
- Seal sump covers
- Aerate leachate storage areas

[15] Flare design depends on the type of flare system which may include open flares or enclosed flares. Retention time and temperature necessary to achieve highly efficient combustion of landfill gas ranges from 0.6-1.0 seconds at 850 degrees Celsius to 0.3 seconds at 1000 degrees Celsius in enclosed flares. Open flares operate at lower combustion temperatures. Additional information on the technical specifications for efficient flaring systems is provided in European Agency, United Kingdom, and Scottish Environment Protection Agency (2002) and World Bank – ESMAP (2003).

Litter

Wind, vehicles, and vermin can disperse MSW, potentially attracting vermin, contributing to transmission of diseases, and adversely affecting wildlife and neighboring communities.

The following measures are recommended to prevent, minimize, and control dispersal of litter:

- Avoid siting of facilities in particularly exposed, windy areas
- Provide perimeter planting, landscaping, or fences to reduce wind;
- Pin waste by use of dozers and landfill compactors immediately after discharge from the vehicles delivering the waste;
- Use soil or artificial cover materials so that deposited waste is held in place. More frequent application of cover may be required during high winds or in exposed areas;
- Use scaring techniques or natural predators to control scavenging birds;
- Provide an emergency tipping area/foul weather cell for lightweight wastes such as paper;
- Construct temporary banks and bunds immediately adjacent to the tipping area, install strategically placed mobile catch fences close to the tipping area or on the nearest downwind crest, and/or fully enclose of the tipping area within a mobile litter net system;
- Install wind fencing upwind of the tipping area to reduce the wind strength as it crosses the facility;
- Temporarily close the facility to specific or all waste or vehicle types when weather conditions are particularly adverse.

Closure and Post-Closure

Landfill facility operators should plan for the closure and post-closure care of the facility. Such planning should take place as early as possible in the project cycle so that potential closure and post-closure issues are incorporated in the financial and technical planning. Closure and post-closure planning activities should include the following elements:[16]

- Development of a closure plan which specifies the necessary environmental objectives and controls (including technical specifications), future landuse (as defined in consultation with local communities and government agencies), closure schedule, financial resources, and monitoring arrangements;
- Evaluation, selection, and application of closure methods consistent with post-closure use and which should include the placement of a final cover to prevent further impacts to human health and the environment;
- Application of final cover components that are consistent with post closure use and local climatic conditions. The final cover should provide long term environmental protection by preventing direct or indirect contact of living organisms with the waste materials and their constituents; minimize infiltration of precipitation into the waste and the subsequent generation of leachate; control landfill gas migration; and minimize long term maintenance needs.
- Financial instruments in place to cover the costs of closure and post-closure care and monitoring.

1.1.2 Industrial Hazardous Waste

Hazardous wastes may be so defined because they share the properties of a hazardous material (e.g. ignitability, corrosivity, reactivity, or toxicity), or other physical, chemical, or biological characteristics which may pose a potential risk to human health or the environment if improperly managed. Wastes may also be defined as "hazardous" by local regulations or international

[16] For additional details on closure and post-closure planning, refer to the EPA's Guide for Industrial Waste Management (http://www.epa.gov/epaoswer/non-hw/industd/guide.htm)

conventions, based on the origin of the waste and its inclusion in hazardous waste lists.

Waste Collection and Transport

Transportation of industrial hazardous waste is a specialized activity requiring appropriate equipment and suitably trained staff. Recommended measures to prevent spills and releases during waste transport and to facilitate emergency response if an accident should occur are provided in the **General EHS Guidelines.** Additional recommendations specifically applicable to hazardous waste collection and transport operations include:

- Follow applicable national regulations and internationally accepted standards for packaging, labeling, and transport of hazardous materials and wastes;[17]
- Use tanks and containers specially designed and manufactured to incorporate features appropriate for the wastes they are intended to carry;
- If drums or other containers are used to transport waste, containers should be in good condition and compatible with the waste and are adequately secured in the transport vehicle;
- Adequately label all transport tanks and containers to identify the contents, hazards, and actions required in various emergency situations.

Waste Receipt, Unloading, Processing, and Storage

Because of the potential inherent hazards of the waste, it is especially important for industrial hazardous waste management facilities to understand and control the nature of the waste that is accepted for storage, treatment, or disposal. Failure to adequately identify and classify incoming waste could result in inadequate treatment or disposal or unintended reactions that could release hazardous substances or cause fires or explosions. Therefore, recommended measures to control waste receipts and general measures to mitigate risks at industrial hazardous waste management facilities include:

- Establish and maintain a close relationship with the waste generator to understand the process generating the waste and to monitor any changes in the process or waste characteristics;
- Sufficient personnel with the requisite qualifications should be available and on duty at all times. All personnel should undergo specific job training;
- Obtain a thorough understanding of the incoming waste. Such knowledge needs to take into account the waste characteristics and variability, the origin of the waste, the treatment and disposal under consideration, the nature of the waste residuals, if any, that may be generated during treatment, and potential risks associated with waste treatment and disposal;
- Implement a pre-acceptance procedure that includes, as applicable, tests of the incoming waste and documentation of the waste source (e.g., the processes producing the waste, including the variability of the process), and identifying the appropriate treatment/disposal;
- Implement an acceptance procedure that includes, as applicable, procedures that limit the acceptance of waste to only that which can be effectively managed including effective disposal or recovery of residuals from waste treatment. Only accept waste if the necessary storage, treatment capacity, and disposition of any treatment residuals (e.g. acceptance criteria of the output by another treatment or disposal facility) are assured. The reception facility should include a laboratory to analyze incoming

[17] See, for example, UN Recommendations on the Transport of Dangerous Goods (Orange Book); U.S. Department of Transportation Regulations at 49 CFR Subtitle B Chapter 1.

waste samples at the speed required by facility operations to determine if the waste is acceptable;

- In the case of treatment, analyze the waste out according to the relevant parameters important for the receiving facility (e.g. landfill or incinerator).

Spills and Releases

Overfills, vehicle accidents, and tank and piping failures can lead to releases during waste storage and handling. Mitigation measures, including physical protection, overfill protection, tank integrity, and secondary containment for tanks are addressed in the **General EHS Guidelines**. Additional recommended measures include:

- Segregate hazardous wastes and materials from non-hazardous wastes and materials;
- Separate incompatible wastes, such as certain alkaline and acidic wastes that would release toxic gases if mixed; keep records of testing; store waste in separate drums or vessels based on their hazard classification;
- Lock out valves controlling material and waste transfer when not in use;
- Waste containers should be suitably labeled to include details of their contents and that their locations are recorded in a tracking system;
- Transfer or decant only one type of material at any one time;
- Conduct regular training and exercises for site staff regarding emergency procedures;
- Provide sufficient firewater containment to prevent uncontrolled discharge of water off site in the event of a fire.

Fires and Explosions

Industrial hazardous wastes can be flammable and reactive; therefore, special precautions are needed when handling these wastes to prevent accidents. Recommended measures to prevent and prepare for fires and explosions are presented in the **General EHS Guidelines**. Additional recommended measures include:

- Fire fighting equipment appropriate to the type of waste received at the site should be available;
- Minimize the storage of flammable liquids on site (e.g. fuel, flammable wastes);
- Use of a nitrogen atmosphere for organic waste liquid with a low flashpoint stored in tanks;
- Perform crushing and shredding operations under full encapsulation and under an inert or exhausted atmosphere for drums and containers containing flammable or highly volatile substances;
- Provide an emergency tipping area for waste loads identified to be on fire or otherwise deemed to be an immediate risk;
- Prepare and annually review a fire risk assessment.

Air Emissions

Air emissions may include releases of particulate matter and VOCs from storage vessels and waste processing equipment. Hazardous waste incineration facilities should minimize leaks from hazardous waste transfer equipment (e.g. pumps, piping, etc) through the implementation of leak detection and repair program.[18] Additional guidance on VOC emissions prevention and control is addressed in the **General EHS Guidelines**. Guidance on emissions prevention and control is also addressed above under the MSW section.

Water Effluents

Storage and processing operations may generate wash water and runoff from waste management areas. General measures

[18] Additional information on VOC emissions prevention programs is provided in 40 CFR Part 264, Subparts BB and CC (http://www.access.gpo.gov/nara/cfr/waisidx_99/40cfr264_99.html)

for runoff control are addressed under MSW above and in the **General EHS Guidelines.** In addition, the following methods are recommended for prevention, minimization, and control of water effluents:

- Collect and treat wash water and runoff from waste storage and handling areas as potentially hazardous, unless analytical tests determine otherwise;
- Segregate runoff from areas storing incompatible wastes.

Biological and Physico-Chemical Treatment

Biological and physico-chemical treatment processes destroy, separate, concentrate, or contain waste materials to minimize potential environmental, health, and safety hazards and to facilitate environmentally sound management of the wastes. These treatments are usually applied to aqueous solutions or sludge. Many of the treatment processes are effective only for specific waste types, and can be compromised by constituents from other waste streams; therefore, waste acceptance procedures discussed above are especially important. Many of the processes in this sector incorporate sophisticated equipment technology requiring highly-trained staff.

General recommended procedures for biological treatment are addressed under MSW, above. General recommended procedures to prevent, minimize, and control potential environmental impacts from chemical treatment include:

- Design and operate facilities in accordance with applicable national requirements and internationally accepted standards;[19]
- Prepare a quality control plan, which may include a definition of personnel rolls, responsibilities, and qualifications, inspection procedures, and documentation etc.;
- Clearly define the objectives and the expected reaction chemistry for each treatment process;
- Assess each new set of reactions and proposed mixes of wastes and reagents in a laboratory-scale test prior to waste treatment;
- Specifically design and operate the reactor vessel so that it is fit for its intended purpose;
- Monitor the reaction so that it is under control and proceeding towards the anticipated result.

Air Emissions

Air emissions associated with storage and transfer operations are discussed above. Additional recommended measures to prevent, minimize, and control air emissions include:

- Enclose treatment and reaction vessels so that they are vented to the air via an appropriate scrubbing or other air emission abatement system;
- Install gas detectors (e.g. suitable for detecting HCN, H_2S, and NO_X) and implement safety measures to prevent releases of potentially toxic gases;
- Link the air space above filtration and dewatering processes to the main air pollution abatement system of the plant, if such a system is in place.

Water Effluents

Waste water from biological and chemical processes includes runoff and leachate (addressed above), pollution control residuals, and waste residuals (e.g., separated aqueous fractions of wastes). General measures for runoff control are addressed under MSW above and in the General EHS Guidelines. Recommended measures to prevent, minimize, and control water effluents include:

[19] See, for example, Basel Convention Technical Guidelines on Hazardous Waste Physico-Chemical Treatment and Biological Treatment, Basel Convention Series/SBC No. 02/09; U.S. EPA regulations at 40 CFP Part 264.

- Add flocculation agents to the sludge and waste water to be treated to accelerate the sedimentation process and to facilitate the further separation of solids or, where practical, use evaporation (which avoids the use of flocculation agents);
- Preventing the mixing of wastes or other streams that contain metals and complexing agents.

Waste Residuals

Biological and chemical treatments typically generate solid waste residuals that must be disposed of. Recommended measures to prevent, minimize, and control solid wastes include:

- Restrict the acceptance of wastes to be treated by solidification/immobilization to those not containing high levels of VOCs, odorous components, solid cyanides, oxidizing agents, chelating agents, high TOC wastes, and compressed gas cylinders.
- Minimize the solubility of metals and reduce the leaching of toxic soluble salts by a suitable combination of water washing, evaporation, re-crystallization, and acid extraction when immobilization is used to treat solid waste containing hazardous compounds prior to landfilling.
- Based on the waste residual's physical and chemical characteristics, solidify, vitrify, melt, or fuse wastes as required/necessary prior to landfill disposal.
- Test the leachability of inorganic compounds (e.g., by using the standardized European Committee for Standardization (CEN) or U.S. EPA leaching procedures) for waste to be landfilled.

Hazardous Waste Incineration

Incineration involves several integrated process operations, including feed control and preparation, combustion, and management of combustion products (e.g., flue gases and ash). Incineration reduces the volume and weight of waste and destroys nearly all of the organic compounds in the waste, but also generates air emissions and waste residues that must be appropriately managed.

To minimize potential environmental, health, and safety impacts, the following general measures should be considered:

- Design and operate incinerators in accordance with applicable national requirements and internationally accepted standards.[20] These standards typically require destruction efficiencies of 99.99 percent to 99.9999 percent, depending on the hazard characteristics of the waste;
- Implement stringent waste selection procedures so that only wastes that can be effectively managed are accepted;[21]
- Continuously monitor incinerator parameters including waste feed rate, total hydrocarbons, temperature (measured at the end of the residence zone), and CO and oxygen (measured a the stack);
- Install an automatic system to prevent feeding of hazardous waste to the incinerator when operating conditions deviate from the acceptable range (e.g., during startup and shutdown or upset conditions).

Air Emissions

Air emissions depend on the waste-feed composition and may include NO_X, SO_2, CO_2, metals, acids, and products of incomplete combustion, most notably polychlorinated dibenzo-p-dioxins and -furans (PCDDs and PCDFs).

[20] See, for example, Basel Convention Technical Guidelines on Incineration on Land, Basel Convention Series/SBC No. 02/04; European Commission Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration, August 2006; and U.S. EPA Regulations at 40 CFR Chapter I Subpart O.

[21] Mercury should be excluded from the waste feed to the maximum extent possible.

Recommended measures to prevent, minimize, and control air emissions include:

- Continuously monitor CO and O_2 to evaluate proper combustion conditions;
- Closely track chlorine content of the waste feed and the feed rates of these and other potential pollutants;;
- Periodically monitor concentrations of PCDDs, PCDFs, other combustion products, and heavy metals in flue gas;
- Reduce the generation and emission of PCDDs and PCDFs, if/when chlorine containing wastes are incinerated, by ensuring rapid cooling of flue gas as well as good turbulence of the combustion gas, high temperature, adequate oxygen content, and adequate residence time. De-NOX systems can also reduce PCDD and PCDF emissions;
- Additional emission controls (e.g., activated carbon) should be installed if necessary;
- Treat combustion gases to remove metals and acid gases (e.g., by wet scrubbers);
- Control fugitive emissions from the combustion zone (e.g., by sealing the combustion zone or maintaining the combustion zone pressure below atmospheric pressure);
- Minimize fugitive emissions of ash (e.g., use of closed systems to handle fine dry material and use of closed containers for transfer to the disposal site).
- Consider the application of waste-to-energy technologies to help conserve resources and off-set emissions associated with fossil fuel based power generation.[22]

Water Effluents

Many air pollution control devices use water for gas cleaning, and generate wastewater that contains the pollutants removed from the flue gas. Recommended measures to prevent, minimize, and control water effluents include:

- Periodically monitor concentrations of PCDDs and PCDFs if/when chlorine containing wastes are incinerated, and other combustion products and heavy metals in wastewater;
- Minimize discharge of process wastewater to the extent possible while maintaining required air emission control;
- Treat wastewater before discharge (e.g., using settling, precipitation of metals, and neutralization).

Ash and Residues

Incinerator bottom ash contains metal oxides and halides, which can have significant water solubility (halides) and can potentially constitute a hazardous waste. Fly ash can absorb water-soluble incomplete combustion products from the flue gas. Thus, contaminants may readily leach from untreated incinerator waste residuals.

Recommended measures to prevent, minimize, and control solid wastes include:

- Treat ash and other solid residue from incineration of industrial hazardous wastes as hazardous unless it can be demonstrated that they are not hazardous;
- Periodically monitor concentrations of PCDDs, PCDFs, other combustion products, and heavy metals in pollution control residues, and ash or slag;
- Reduce the potential for leaching from ash residues (e.g., by solidification or vitrification) prior to final disposition.

[22] As previously noted, the possibility of applying waste-to-energy technologies depends on a number of issues which may include the project design specifications established by local government as well as laws applicable to the generation and sale electricity.

Landfilling

Hazardous constituents in landfilled industrial hazardous wastes can potentially migrate from the landfill as leachate or in the gas phase. Therefore, design and operation criteria are particularly important for landfills that accept industrial hazardous waste so that the waste remains contained during the operating life of the landfill, including after closure of the landfill.

General recommended measures to prevent, minimize, and control potential environmental impacts from landfilling of industrial hazardous wastes include:

- Design and operate the landfill in accordance with applicable national requirements and internationally accepted standards;[23]
- Divide the landfill into different cells to separate wastes with different properties;
- Maintain records of the wastes received, including sources, analytical results, and quantity;
- Record on a map the location and dimensions of each landfill cell and the approximate location of each hazardous waste type within the landfill cell.

Leachate Generation

Storm water controls are addressed under MSW landfills, above, and in the General EHS Guidelines. In addition, recommended measures to prevent, minimize, and control leachate generation include:

- Install a liner system, preferably consisting of two or more liners with a leachate collection system above and between the liners, to prevent migration of wastes out of the landfill to the adjacent subsurface soil or ground water or surface water at anytime during the active life of the landfill and after closure, as long as the wastes remain hazardous. The liners should be:
    - o Constructed of low-permeability materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients, physical contact with the waste or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation;
    - o Placed upon a foundation or base capable of providing support to the liner and resistance to pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression, or uplift;
    - o Installed to cover all surrounding earth likely to be in contact with the waste or leachate.
- Install a leachate collection and removal system immediately above the upper liner to collect and remove leachate from the landfill so that leachate depth over the liner does not exceed 30 cm. The leachate collection and removal system should be:
    - o Constructed of materials that are chemically resistant to the waste managed in the landfill and the leachate expected to be generated and of sufficient strength and thickness to prevent collapse under the pressures exerted by overlying wastes, waste cover materials, and by any equipment used at the landfill;
    - o Designed and operated to function without clogging through the scheduled closure of the landfill.
- In a two-liner system, install a leak detection system between the liners. This leak detection system should be capable of detecting, collecting, and removing leaks of hazardous constituents at the earliest practicable time through all areas of the top liner likely to be exposed to waste or leachate;

[23] See, for example, Basel Convention Guidelines on Specially Engineered Landfill, Basel Convention Series/SBC No. 02/03; and U.S. EPA Regulations at 40 CFR Chapter I Subpart N.

- At final closure of the landfill or upon closure of any cell, cover the landfill or cell with a final cover designed and constructed to:
  - Provide long-term minimization of migration of liquids through the closed landfill;
  - Function with minimum maintenance;
  - Promote drainage and minimize erosion or abrasion of the cover;
  - Accommodate settling and subsidence so that the cover's integrity is maintained; and
  - Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils.

Groundwater and Leachate Monitoring

Groundwater monitoring is addressed under MSW landfills, above. In addition, recommended measures for leachate and site inspections and monitoring include:

- During construction, inspect the liners for uniformity, damage, and imperfections.
- Inspect the landfill regularly (e.g., after storms and weekly during operation and quarterly after closure) to detect evidence of any of deterioration, malfunctions, or improper operation of run-on and run-off control systems, such as erosion of the final cover; proper functioning of wind dispersal control systems, where present; and the presence of leachate in and proper functioning of leachate collection and removal systems.

Landfill Gas

If biodegradable wastes are disposed of, landfill gas can be generated and should be controlled and monitored, as described for MSW landfills, above.

Closure and Post-Closure

Landfill facility operators should plan for the closure and post-closure care of the facility as described previously (see Municipal Solid Waste – Landfills).

1.1.3 Industrial Non-Hazardous Waste

Solid industrial non-hazardous wastes are defined through national legislation as they originate from industrial sources but do not meet the definition of hazardous waste with regards to their specific origin within the industrial process or its characteristics. Examples of non-hazardous industrial wastes include any garbage, refuse, or sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility, and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial operations; inert construction / demolition materials; refuse, such as metal scrap and empty containers; and residual waste from industrial operations, such as boiler slag, clinker, and fly ash.

Waste Collection and Transport

Transportation of industrial non-hazardous waste requires appropriate equipment and suitably trained staff, and mitigation measures described above for hazardous waste can be generally applicable to industrial non-hazardous waste. Additional recommended measures to prevent, minimize, and control potential environmental risks associated with waste collection and transport include:

- Vehicles and other equipment used for collection industrial non-hazardous wastes should not be used for collection of MSW without prior cleaning to remove waste residues.

- Vehicles and other equipment used for collection industrial non-hazardous wastes should not be used for distribution of goods (e.g., mulch).

Waste Receipt, Unloading, Processing, and Storage

As with MSW and industrial hazardous waste, facilities managing industrial non-hazardous waste should understand and control the nature of the waste that is accepted for storage, treatment, or disposal so that the waste can be managed safely and effectively. Waste acceptance and analysis procedures should be implemented considering the nature and expected variability of the incoming waste streams, and generally should be similar to measures suggested for industrial hazardous waste management facilities, described above.

Biological and Physico-Chemical Treatment

Treatment of non-hazardous industrial waste can help to reduce the volume and toxicity of waste prior to disposal. Treatment can also make a waste amenable for reuse or recycling. Consequently, a facility managing non-hazardous industrial waste might elect to apply treatment. For example, treatment might be incorporated to address small quantity VOC emissions from a waste management unit, or a facility might elect to treat a waste so that a less stringent waste management system design could be used. Treatment and post-treatment waste management methods can be selected to minimize environmental impact, keeping in mind that treatment residuals, such as sludge, are wastes themselves that will need to be managed. In general, recommended mitigation measures are similar to those for industrial hazardous waste treatment facilities, discussed above.

Incineration

Incineration might be considered for industrial non-hazardous wastes, including solids, and especially liquids, with heat value that can be recovered during incineration. Recommended mitigation measures for industrial hazardous waste incineration facilities, discussed above, should be considered and adopted for industrial non-hazardous incineration facilities as appropriate, based on the nature of the incoming waste stream.

Landfilling

Industrial non-hazardous waste landfills, like other landfill facilities, depend on waste containment, including leachate collection and treatment (and where appropriate, gas management) to control potential hazards associated with the waste. Industrial non-hazardous waste landfills might accept only one type of waste (i.e., monofills), or a variety of wastes. The nature of the incoming wastes will determine whether the design and controls are more similar to MSW or industrial hazardous waste landfills. In addition to measures discussed for MSW and industrial hazardous waste landfills, the following measures are recommended to prevent, minimize, and control potential environmental impacts associated with industrial non-hazardous waste landfills.

- Comply with applicable national and local requirements and internationally accepted standards for industrial non-hazardous waste landfills, including provisions for monitoring; [24]
- Do not dispose of putrescible wastes, unless the facility is equipped to manage these types of wastes, with landfill gas collection and treatment systems and degradation products will not interact with the other industrial wastes in a manner that would increase their toxicity or mobility;
- Do not dispose of liquids, explosive wastes, radioactive or nuclear materials, or medical wastes

[24] See, for example, Basel Convention Guidelines on Specially Engineered Landfill, Basel Convention Series/SBC No. 02/03; U.S. EPA regulations at 40 CFR Part 257; and 30 Texas Administrative Code Chapter 335.

together with non-hazardous industrial wastes or by landfilling;

- Design the landfill systems, including selection of liner and cover materials, so that industrial wastes and degradation products are contained;
- Monitor groundwater and surface water quality in the vicinity of the facility in a manner similar to that recommended for industrial hazardous waste management facilities;
- Develop and follow a written schedule for inspecting monitoring equipment, safety and emergency equipment, and operating and structural equipment (such as dikes and sump pumps) that are important to preventing, detecting, or responding to potential environmental or human health hazards;
- Implement a training program so that facility personnel are able to respond effectively to emergencies by familiarizing them with emergency procedures, emergency equipment, and emergency systems.

1.2 Occupational Health and Safety

Occupational health and safety impacts during the construction and decommissioning of waste management facilities are common to other large industrial projects and are addressed in the **General EHS Guidelines**. The most significant occupational health and safety impacts typically associated with workers at waste management facilities occur during the operational phase and include:

- Accidents and injuries
- Chemical exposure
- Exposure to pathogens and vectors

Accidents and Injuries

Physical hazards encountered at waste management facilities are similar to those at other large industrial projects and are addressed in the **General EHS Guidelines**. Solid waste workers are particularly prone to accidents involving trucks and other moving equipment, so traffic management systems and traffic controllers are recommended. Accidents include slides from unstable disposal piles, cave-ins of disposal site surfaces, fires, explosions, being caught in processing equipment, and being run over by mobile equipment. Other injuries occur from heavy lifting, contact with sharps, chemical burns, and infectious agents. Smoke, dusts, and bioaerosols can lead to injuries to eyes, ears, and respiratory systems.[25]

Mitigation measures for accidents and injuries are partially addressed in the **General EHS Guidelines**. In addition, the following procedures are recommended to prevent, minimize, and control accidents and injuries at waste management facilities:

- In landfills, conduct compaction of wastes in thin layers using heavy equipment and place regular cover material over each compacted layer of waste, so that any underground fires within a waste cell are not able to spread throughout the landfill and lead to significant cave-ins;
- Ventilate landfill gas so that underground fires and explosions do not occur;
- Use maximum side slopes of 3:1 in non-seismic areas and lower slopes (e.g., 5:1) in seismic areas, with regular drainage of water so that saturated conditions do not develop and lead to slope subsidence;
- Provide workers with appropriate protective clothing, gloves, respiratory face masks and slip-resistant shoes for waste transport workers and hard-soled safety shoes for all

[25] Refer to Cointreau. S. (2006) for additional information.

workers to avoid puncture wounds to the feet. For workers near loud equipment, include noise protection. For workers near heavy mobile equipment, buckets, cranes, and at the discharge location for collection trucks, include provision of hard hats;

- Provide all landfill equipment with enclosed air conditioned cabs and roll-over protection;
- Provide refuse collection vehicles and landfill equipment with audible reversing alarms and visible reversing lights;
- Improve the storage of solid wastes at the source so that the loads to be collected are well contained and not too heavy;
- Locate exhaust pipes on waste collection vehicles so that exhaust does not discharge into the breathing zone of workers on the riding steps;
- Design collection routes to minimize, or possibly eliminate, crossing traffic that is going in the opposite direction;
- Provide two-hand constant-pressure controls for collection vehicles with compaction mechanisms;
- Restrict access to disposal sites such that only safety-trained personnel with protective gear are permitted to high-risk areas;
- Segregate people from operating trucks in recycling and transfer stations;
- Use automated systems to sort and transfer waste to the extent practical in order to minimize contact with the waste;
- Provide workers with communications tools, such as radios. Special signaling codes have been developed for communications on landfill sites;
- Minimize sorting from the ground by providing conveyor belts and/or tables that facilitate sorting;
- Establish engineering and materials norms for special facility and stationary equipment design requirements that minimize exposure to hazards (e.g., ventilation, air conditioning, enclosed conveyor belts, low loading and sorting heights, non-skid flooring, safety rails on stairs and walkways, spill protection and containment, noise control, dust suppression, gas alarm systems, fire alarm and control systems, and evacuation facilities).

Chemical Exposure

Chemical hazards encountered at waste management facilities are similar to those at other large industrial facilities, such as toxic and asphyxiating gases, and are addressed in the **General EHS Guidelines**. However, the full composition of wastes and their potential hazards is often unknown. Even municipal solid waste (MSW) often contains hazardous chemicals, such as heavy metals from discarded batteries, lighting fixtures, paints, and inks.

The following procedures are recommended to prevent, minimize, and control chemical exposure at waste management projects:

- Control and characterize incoming waste (see waste receipt, unloading, processing and storage);
- Provide adequate personnel facilities, including washing areas and areas to change clothes before and after work;
- Ventilate enclosed processing areas (e.g., dust in waste size reduction areas, VOCs driven off by high temperatures during composting);
- Monitor breathing zone air quality in work areas at processing, transfer and disposal facilities. Direct-reading instruments that measure methane and oxygen deficiency are of primary importance; these include combustible gas indicators, flame ionization detectors, and oxygen meters. At waste treatment/disposal facilities, volatile organics should also be analyzed in the biodegradation gases being collected and/or vented. In waste handling, sorting, and composting facilities, monitoring for organic dust is needed;

- Prohibit eating, smoking, and drinking except in designated areas;
- Provide air filtered and air conditioned cabs for heavy mobile equipment used at landfills as necessary.

Dust

Waste processing can generate nuisance and hazardous dust, including organic dust. Dust control measures discussed in Section 1.1 above, will also help to reduce worker exposure to dusts. General mitigation measures for dust are also addressed in the **General EHS Guidelines**.

Pathogens and Vectors

Workers can be exposed to pathogens contained in manure and animal excreta found in MSW from the disposal of sludge, carcasses, diapers, and yard trimmings containing domestic animal waste. Uncontrolled dumping of MSW attracts rats, flies, and other insects that can transmit diseases. Processing of MSW can also generate bioaerosols, suspensions of particles in the air consisting partially or wholly of microorganisms, such as bacteria, viruses, molds, and fungi. These microorganisms can remain suspended in the air for long periods of time, retaining viability or infectivity. Workers may also be exposed to endotoxins, which are produced within a microorganism and released upon destruction of the cell and which can be carried by airborne dust particles.

The following measures are recommended to prevent, minimize, and control pathogens and vectors:

- Provide and require use of suitable personal protective clothing and equipment;
- Provide worker immunization and health monitoring (e.g. for Hepatitis B and tetanus);
- Maintain good housekeeping in waste processing and storage areas;
- Use automatic (non-manual) waste handling methods if practical;
- For landfills, promptly emplace, compact and cover of wastes in defined cells, especially for waste with the potential to attract vermin and flies, such as food wastes (especially animal by-products if accepted at the facility) and tannery wastes;
- Clean and wash with disinfectant the cabins of heavy mobile equipment used at regular intervals;
- For composting, maintain aerobic conditions and proper temperatures in the windrows. Isolate workers from spore-dispersing components of the composting process such as mechanical turning (e.g., by using tractors or front-end loaders with enclosed air-conditioned or heated cabs). Aeration systems are preferred over manual turning;
- Maintain adequate temperature and retention time in biological treatment systems to achieve pathogen destruction (e.g., 55ºC for at least 3 consecutive days in most compost situations and 55ºC for 15 days in windrows);
- Grade the area properly to prevent ponding (to minimize insect breeding areas);
- Use integrated pest-control approaches to control vermin levels, treating infested areas, such as exposed faces and flanks with insecticide, if necessary;

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- Provide and require use of dust masks or respirators under dry and dusty conditions (e.g., when compost is being turned). Charcoal-filled respirators also reduce odor perception;
- Provide prompt medical attention for cuts and bruises. Cover open wounds to prevent contact with the incoming loads or feedstock;

- Fully enclose the waste management site with fencing so that no livestock or wildlife is able to come in contact with the waste, which contains significant potential to enable the spread of livestock and zoonotic disease, as well as spillover disease to wildlife. Provide daily cover of wastes to minimize the attraction to birds, which can become infected with avian influenza and other bird diseases that can then be carried off-site.

1.3 Community Health and Safety

Community health and safety issues related to the construction of waste management projects may include emissions from the solid wastes and construction site issues which are addressed in the General EHS Guidelines..

Community health and safety impacts which occur during the operational and decommissioning phases of waste management facilities may include:

- General occupational and environmental health issues associated with waste scavenging
- Physical, chemical, and biological hazards
- Litter
- Noise
- Dust and odors

General Occupational and Environmental Health Issues Associated with Waste Scavenging

The presence of informal sector workers laboring in municipal or mixed waste disposal sites in search of commercially valuable materials is a common place occurrence in developing countries. The causes and dynamics are the result of complex social, cultural, labor, and economic factors that are clearly outside of the scope of this guidance document. However, the following principles should be considered in managing the occupational, health, and safety risks of informal laborers:

- Waste scavenging should not be allowed under any circumstances in hazardous and non-hazardous industrial waste management facilities;
- Facilities dedicated to the management of MSW should work with government entities in the development of simple infrastructure that can allow for the sorting of waste, helping groups of scavengers form cooperatives or other forms of micro-enterprises, or formally contracting them to provide this function. The outright displacement of scavenging workers as an occupational health and safety management strategy, without the provision of viable alternatives, should be avoided;
- Operators of existing facilities with scavenging workers should exercise commercially viable means of formalizing their work through the creation of management programs that include:
  - Allowing only registered adults on the site, excluding children and domestic animals. Striving to provide alternatives to access to childcare and education to children;
  - Providing protective gear, such as shoes. face masks, and gloves;
  - Arranging the disposal layout and provide sorting facilities to improve access to recyclables while reducing their contact with other operations, thus minimizing potential hazards;
  - Providing water supply for washing and areas for changing clothes;
  - Implementing education campaigns regarding sanitation, hygiene, and care of domestic animals;
  - Providing a worker health surveillance program including regular vaccination and health examinations.

Physical, Chemical, and Biological Hazards

Visitors and trespassers at waste management facilities may be subject to many of the hazards described for site workers. In particular, waste pickers, looking for recyclable materials and food scraps for animal feeding, often work informally at waste transfer and disposal sites, especially MSW facilities, typically living adjacent to the site in poor housing conditions, with minimal basic infrastructure for clean water and sanitation. Waste pickers may be encounter numerous risks, including contact with human fecal matter, paper that may have become saturated with toxic materials, bottles with chemical residues, metal containers with residue pesticides and solvents, needles and bandages (containing pathogenic organisms) from hospitals, and batteries containing heavy metals. Exhaust fumes of waste collection trucks traveling to and from disposal sites, dust from disposal operations, and open burning of waste all contribute to potential occupational health problems.[26]

Recommended measures to prevent, minimize, and control physical, chemical, and biological hazards to the community include:

- Restrict access to waste management facilities by implementing security procedures, such as:
  - Perimeter fencing of adequate height and suitable material, e.g. chain link, stock proof palisade;
  - Lockable site access gate and buildings;
  - Security cameras at key access points linked to recording equipment and remote access CCTV, where required;
  - Security alarms fitted to buildings and storage areas;
  - Review of site security measures annually or whenever a security breach is reported
  - Use of a site visitor register;
  - Immediate repair of fencing/access points if damaged; and
  - Lighting of site during night time where necessary. As this may cause light nuisance to neighbors, the lighting installations should be selected to minimize ambient light pollution.

Litter

Uncollected garbage and litter spread beyond the waste management facility boundaries by wind, vermin, and vehicles can directly spread disease; attract rats, flies, and other vectors; and expose the community to hazardous substances. Scavenging birds, such as gulls and crows, commonly congregate on landfill sites accepting household waste. They disturb newly tipped and partially covered waste whilst searching for food, and lead to complaints from adjoining residents and landowners about food scraps, excreta and other waste dropped away from the landfill. Litter control is addressed in Section 1.1, above.

Noise

Noise is typically generated by waste processing and treatment equipment as well as vehicular traffic on the site and bringing waste and materials to and from the facility. Sources of noise and abatement measures are addressed in Section 1.1, above, and the General EHS Guideline. In addition, facility operators should coordinate hours of operation with adjacent land uses.

Dust and Odors

Dust and odors from waste management facilities can be a nuisance to the neighboring community. Organic dust can also carry disease-causing microorganisms. Dust and odor controls are addressed in Section 1.1 and in the **General EHS Guidelines**. In addition, the following measures are recommended to prevent, minimize, and control community exposure to dust and odors from waste management facilities:

[26] Sandra Cointreau, The World Bank Group, Occupational and Environmental Health Issues of Solid Waste Management Special Emphasis on Middle- and Lower-Income Countries, Urban Papers UP-2, July 2006.

- Provide adequate buffer area, such as hills, trees, or fences, between processing areas and potential receptors.
- Avoid siting facilities near densely populated neighborhoods and installations with potentially sensitive receptors, such as hospitals and schools. Site facilities downwind from potential receptors, if possible.

2.0 Performance Indicators and Industry Benchmarks

2.1 Environmental Performance

Emissions and Effluents

Tables 1 through 4 present examples of emissions and effluent standards for waste management facilities from the European Union and the United States for this sector.[27] These emissions and effluent values are assumed to be achievable under normal operating conditions in appropriately designed and operated facilities through the application of pollution prevention and control techniques discussed in the preceding sections of this document. These levels should be achieved at all times as described in the above-referenced standards. Deviation from these levels in consideration of specific, local project conditions should be justified in the environmental assessment.

Effluent guidelines are applicable for direct discharges of treated effluents to surface waters for general use. Site-specific discharge levels may be established based on the availability and conditions in the use of publicly operated sewage collection and treatment systems or, if discharged directly to surface waters, on the receiving water use classification as described in the General EHS Guideline. These levels should be achieved, without dilution, at least 95 percent of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours. Deviation from these levels in consideration of specific, local project conditions should be justified in the environmental assessment.

Environmental Monitoring

Environmental monitoring programs for this sector should be implemented to address all activities that have been identified to have potentially significant impacts on the environment, during normal operations and upset conditions. Environmental monitoring activities should be based on direct or indirect indicators of emissions, effluents, and resource use applicable to the particular project.

Monitoring frequency should be sufficient to provide representative data for the parameter being monitored. Monitoring should be conducted by trained individuals following monitoring and record-keeping procedures and using properly calibrated and maintained equipment. Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Additional guidance on applicable sampling and analytical methods for emissions and effluents is provided in the **General EHS Guidelines**.

[27] Sources should be consulted directly for the most updated information.

2.2 Occupational Health and Safety Performance

Occupational Health and Safety Guidelines

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include the Threshold Limit Value (TLV®) occupational exposure guidelines and Biological Exposure Indices (BEIs®) published by American Conference of Governmental Industrial Hygienists (ACGIH), the United States National Institute for Occupational Health and Safety (NIOSH), Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United States (OSHA), Indicative Occupational Exposure Limit Values published by European Union member states, or other similar sources.

Accident and Fatality Rates

Projects should try to reduce the number of accidents among project workers (whether directly employed or subcontracted) to a rate of zero, especially accidents that could result in lost work time, different levels of disability, or even fatalities. Facility rates may be benchmarked against the performance of facilities in this sector in developed countries through consultation with published sources (e.g. US Bureau of Labor Statistics and UK Health and Safety Executive).

Occupational Health and Safety Monitoring

The working environment should be monitored for occupational hazards relevant to the specific project. Monitoring should be designed and implemented by credentialed professionals as part of an occupational health and safety monitoring program. Facilities should also maintain a record of occupational accidents and diseases and dangerous occurrences and accidents. Additional guidance on occupational health and safety monitoring programs is provided in the **General EHS Guidelines**

Table 1. Air Emission Standards for MSW Incinerators in the EU and US

Parameter	EU	USA[a]
Total Suspended Particulates	10 mg/m3 (24-hr average)	20 mg/dscm
Sulfur Dioxide (SO_2)	50 mg/m3 (24-hr average)	30 ppmv (or 80% reduction)[b]
Oxides of Nitrogen (NO_X)	200 – 400 mg/m3 (24-hr average)	150 ppmv (24-hr average)
Opacity	n/a	10%
Hydrochloric Acid (HCl)	10 mg/m3	25 ppmv (or 95% reduction)[b]
Dioxins and Furans	0.1 ng TEQ/m3 [6 – 8 hr average]	13 ng/dscm (total mass)
Cadmium	0.05 – 0.1 mg/m3 [0.5 – 8 hr average]	0.010 mg/dscm
Carbon Monoxide (CO)	50 – 150 mg/m3	50 – 150 ppmv[c]
Lead (Pb)	(See Total Metals below)	0.140 mg/dscm
Mercury (Hg)	0.05 – 0.1 mg/m3 [0.5 – 8 hr average]	0.050 mg/dscm (or 85% reduction)[b]
Total Metals	0.5 – 1 mg/m3 [0.5 – 8 hr average]	n/a
Hydrogen fluoride (HF)	1 mg/m3	n/a

Sources:
- EU Directive 2000/76/EC (applicable to MSW and Hazardous Waste Incinerators)
- US EPA Standards of Performance for Large Municipal Waste Combustors, 40 CFR Part 60 Subpart Eb.

Notes:
a All values corrected to 7% oxygen
b Whichever is less stringent
c Depending on the type of unit: modular starved air, and modular excess air—50 ppm (4-hr average); mass burn waterwall, mass burn refractory, and circulating fluidized bed combustor—100 ppm (4-hr average); mass burn rotary waterwall—100 ppm (24-hr average); pulverized coal/refuse-derived fuel mixed fuel-fired combustor—150 ppm (4-hr average); refuse-derived fuel stoker, and spreader stoker coal/refuse -derived fuel mixed fuel-fired combustor—150 ppm (24-hr average).
mg/m3 = milligrams per cubic meter; mg/dscm = milligrams per dry standard cubic meter; ppmv = parts per million by volume; TEQ = Toxicity Equivalent Units;

Table 2. Air Emission Standards for Hazardous Waste Incinerators in the EU and US

Parameter	EU	US [a]
Particulate Matter	See Table 1	1.5 mg/dscm
Carbon Monoxide (CO) or Hydrocarbons (HC)	See Table 1	100 (CO) ppmv 10 (HC) ppmv
Total Chlorine (HCl, Cl_2)	See Table 1	21 ppmv
Mercury (Hg)	See Table 1	8.1 µg/dscm
Semi-Volatile Metals (Pb, Cd)	See Table 1	10 µg/dscm
Low Volatile Metals (As, Be, Cr)	See Table 1	23 µg/dscm
Dioxins and Furans	See Table 1	0.11 dry APCD or WHB 0.20 other sources (ng TEQ/dscm)
Destruction and Removal Efficiency	See Table 1	99.99% – 99.9999%

Source:
US EPA National Emission Standards for Commercial and Industrial Solid Waste Incineration Units, 40 CFR Part 63 Subpart EEE.
Notes:
a All values corrected to 7% oxygen
TEQ = toxicity equivalent; APCD = air pollution control device; WHB = waste heat boiler, mg/m3 = milligrams per cubic meter; mg/dscm = milligrams per dry standard cubic meter; ppmv = parts per million by volume;

Table 3. Air Emission Standards for Industrial Non-Hazardous Waste Incinerators in the EU and US

Parameter	EU	US [a]
Opacity	See Table 1	10%
Particulate Matter	See Table 1	70 mg/dscm
Carbon Monoxide (CO)	See Table 1	157 ppmv
Oxides of Nitrogen (NO_X)	See Table 1	388 ppmv
Sulfur Dioxide (SO_2)	See Table 1	20 ppmv
Hydrogen Chloride (HCl)	See Table 1	62 ppmv
Cadmium (Cd)	See Table 1	4 µg/dscm
Lead (Pb)	See Table 1	40 µg/dscm
Mercury (Hg)	See Table 1	470 µg/dscm
Dioxins and Furans	See Table 1	0.41 ng TEQ/dscm [b]

Source:
US EPA National Emission Standards for Commercial and Industrial Solid Waste Incineration Units , 40 CFR Part 60 Subpart CCCC.
Notes:
a. All values corrected to 7% oxygen. Based on 3-run average (1-hr minimum sample time per run), except for opacity, which is based on 6-minute averages.
mg/m3 = milligrams per cubic meter; mg/dscm = milligrams per dry standard cubic meter; ppmv = parts per million by volume; TEQ = toxicity equivalent.

Table 4—Effluent Standards for Landfills in the US

Parameter	Units	Guideline[c]			
		Hazardous Waste Landfills		MSW Landfills	
		Daily Max	Monthly Avg.	Daily Max	Monthly Avg.
BOD_5		220	56	140	37
pH		6-9	6-9	6-9	6-9
Total Suspended Solids	mg/L	88	27	88	27
Ammonia (as N)	mg/L	10	4.9	10	4.9
Arsenic	mg/L	1.1	0.54		
Chromium	mg/L	1.1	0.46		
Zinc	mg/L	0.535	0.296	0.20	0.11
a-Terpineol	mg/L	0.042	0.019	0.033	0.016
Analine	mg/L	0.024	0.015		
Benzoic Acid	mg/L	0.119	0.073	0.12	0.071
Naphthalene	mg/L	0.059	0.022		
p-Cresol	mg/L	0.024	0.015	0.025	0.014
Phenol	mg/L	0.048	0.029	0.026	0.015
Pyridine	mg/L	0.072	0.025		

Source: U.S. EPA Effluent Guidelines for Centralized Waste Treatment, 40 CFR Part 437.

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Annex A: General Description of Industry Activities

Description and Definition of Wastes

Municipal Solid Waste

Municipal Solid Waste (MSW) typically includes household refuse, institutional wastes, street sweepings, commercial wastes, as well as construction and demolition debris. MSW is extremely variable in composition, depending on the income and lifestyle of the generators. MSW may include paper and packaging materials; foodstuffs; vegetable matter such as yard debris; metal; rubber; textiles; and potentially hazardous materials such as batteries, electrical components, paint, bleach, and medicines. In developing countries, MSW may also contain varying amounts of industrial wastes from small industries, as well as dead animals and fecal matter. In general, and the content of organic waste in developing countries (up to 70 – 80 percent) is higher than in industrialized countries, and the content of packaging waste is lower, making MSW in developing countries relatively dense and moist.

Industrial Waste

The waste categories generated within the industrial enterprises depend on the manufacturing processes and waste management practices. In some cases, sector-specific waste arising within industrial facilities is disposed of at the municipal landfill. These types of waste may consist of slag from iron works and steel mills, ashes, residues from flue gas cleaning, bark, wood, sawdust, cutting fluids, waste oil, organic waste from food industry, and sludges (organic and non-organic). Some of the waste types generated within the industries can be hazardous.

Waste Collection and Transportation

Household waste typically is collected from individual households at the curbside or from neighborhood collection stations with dedicated containers or bins.

Collection vehicles may range from horse-drawn carts, to pickup trucks, to back-loaded and compacting vehicles with a capacity of about 6 – 10 cubic meter (or up to 10 tons). One of the most common problems in developing countries has traditionally been the lack of household waste collection service in low-income neighborhoods with poor road infrastructure; in these settings, smaller vehicles are usually most effective.

Depending on the type, characteristics, volume, and compatibility of different categories of hazardous waste, generators may store them in containers, bins, drums, or aboveground or underground tanks, etc. These types of wastes are typically transported to the treatment or disposal facilities in trucks (for drums, bins or containers) or if larger volumes in tanker trucks.

Transfer Stations

Transfer stations serve as collection points for garbage and brush trucks to transfer their loads to other long haul vehicles. The small collection trucks unload the waste onto a concrete floor or into a hopper; the waste is then compacted further and loaded into containers (typically with a capacity of 20 cubic meters) or directly into specially designed semi trailers. As a rule of thumb, to optimize and reduce the number of trips to the treatment/disposal facility, transfer stations might be preferred if the distance to the treatment/disposal facility exceeds 30 km. In some cases, the distance to the treatment/disposal facility can be shorter and still be viable if the road conditions are poor.

Reception of Waste

When the collection vehicles or the long haul vehicles reach the treatment or disposal facility, the waste should be inspected visually and controlled that the paperwork corresponds to the actual load. In some cases, samples of the waste are taken and analyzed, (e.g., if the waste will be treated biologically where the end-product is utilized and there are demands for low contaminant concentrations such as heavy metals).

Waste Treatment and Disposal

Biological Treatment

Composting

Generally speaking, the purpose of the composting process is to decompose organic solids in the presence of air and humidity, producing a humic substance valuable as soil conditioner. Economic advantages include the reduction in the volume of waste deposited in landfills (extending the life of the landfill and avoiding or delaying the construction of additional ones), and the generation of commercially valuable agricultural nutrients.

Waste categories that are ideal for composting are park, yard and garden waste, paper, paper packaging, food scraps, animal manure and other types of organic waste. If animal waste is composted, the waste should be hygienized prior to composting.

There are several methods available for central composting; the most common and simple is windrow composting where the waste is distributed in rows with the application of oxygen from underlying active or passive ventilation systems. Other methods include closed systems such as drums, tunnel, and membrane methods. The operational conditions and odor generation of closed systems are typically easier to control and are definite advantages over open treatment methods.

Anaerobic Digestion

Anaerobic digestion facilities are ideal for the treatment of the same types of organic waste that can be composted including wastes from households food scraps, paper tissue, garden waste like grass cuttings, leaves; food processing waste such as vegetables, cheese, meat, sugar; manure and animal waste; slaughterhouse waste; sewage sludge; and crop waste.

The quality requirements of the incoming waste to the digestion facility are typically higher than in composting requiring a more homogenized and heterogeneous waste.

Organic waste is treated in closed containers in the absence of air enhancing the generation of biogas (about 55-70 % methane) which can be recovered for subsequent use as a fuel source. The semi-solid residue (digestate) is normally treated through aerobic digestion and may be used as agricultural fertilizer.

Chemical and Physical Treatment

Chemical and physical treatment methods are varied and complex but may include: absorption, evaporation, distillation, filtration, chemical oxidation/reduction, neutralization, precipitation, solvent extraction, stripping / desorption, membrane-based separation, ion exchange, and solidification. Treatment systems may include one of these or a combination of multiple treatment operations. As most of these systems operate on a continual basis, they require a reliable, preferably homogenous source of material.

Incineration

Thermal treatment in incineration facilities can be used for all types of organic waste, including hazardous waste and mixed household waste. MSW incinerators reduce the volume of waste by about 90% and the weight by approximately 75%, while hazardous waste incinerators may achieve much higher waste volume and weight reductions, depending on the inorganic content of the wastes. Some incinerators today in operation are waste-to-energy facilities, which may use the combustion process to generate steam and electricity. Waste-to-energy facilities can be either mass burn or refuse-derived-fuel facilities. Incineration facilities typically range in size from 15,000 tons of waste per year to 500,000 tons per year. In mass burn facilities, wastes are injected into the boiler without any pre-processing or sorting of non-combustible materials.

Most mass burning facilities use grate incinerators and operated at temperatures of at least 850ºC with higher temperatures applied to hazardous wastes. Flue gas treatment is typically required regardless of the type of incineration system. Residual wastes generated from the incineration process include slag, ashes, and flue gas treatment residues.

Landfilling

Landfilling can be used for most waste categories, but ideally only for inert material. A modern sanitary landfill is an engineered facility for the disposal of municipal solid waste designed and operated to minimize public health and environmental impacts.

The typical landfill consists of several cells in which the waste is systematically placed. Compactors may be used to reduce the waste volume and to enhance the build up of the cells. The landfill base usually consists of a liner that minimizes the leakage of liquid waste materials from the landfill into the groundwater system. As the waste is built up in layers it is covered daily to prevent paper, dust or odors from escaping into the environment. The leachate that is generated can be collected and treated. If organic waste is landfilled, landfill gas will be generated and may be collected and utilized or flared.